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Application Experience of Gas-Thermal Aluminum Coatings to Protect the Pipes for Underground Construction and Repair of Heat Networks

A. S. Kolpakov

Ural Federal University, ul. Mira 19, Yekaterinburg, 620002 Russia

Abstract—Questions of sacrificial protection for pipes of underground heat networks with aluminum against the external corrosion are considered. The description of pilot production of pipes with a plasma aluminum coating and the deposition of a sacrificial gas-plasma aluminum coating on weld joints of pipelines and the zone of their thermal influence during assemblage is presented. Examples of repairing the segments of distribution heat networks by the pipes with the tread protection are presented.

Keywords: heat networks, external corrosion, sacrificial protection, gas-thermal aluminum coatings

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Heat networks of underground construction are exploited in conditions favorable for the development of corrosion processes [1]. Internal corrosion damages associated with unsatisfactory quality of makeup water and the use of low-quality pipes are usually not a dominant factor in statistics of accidents and damages in heat networks of large cities. The main cause is the external corrosion of the pipes [2].

Thus, the operational reliability of pipelines and periodicity of their repair and replacement are determined by the degree of corrosion destruction of steel situated in close contact with heat insulation [3, 4]. The largest damage is observed at segments of heat networks where humidification of the insulation is a usual phenomenon. Such segments are heat chambers and zones of impoundment of heating mains with underground waters. In the last case, the service life of heating mains both for lying in inaccessible channels and for channel-free lying is 10–12 years, which is lower than regulatory characteristics by a factor of 2 [5].

Preinsulated pipes in a polyethylene shell do not solve the problem because of the systematic violation of technical recommendations of producer plants on assemblage of the pipes and bedding-in the weld joints [6]. Damages of a waterproof layer and polyurethane foam moistening can lead to the enhanced corrosion of a pipeline and its mortality already in 2 years [5]. A system for operative remote monitoring of insulation humidity should be organized at such heating mains. In addition to the rise in cost of the pipe itself, this leads to the necessity of installation of the additional automatic equipment and participation of service staff. Limitations on the heat-carrier temperature (lower than 130°C) and possibilities of channel-free lying are generally known [7]. In addition, there is no experience on the prolonged exploitation of preinsulated pipes with the high-quality control of the heat load of the main [8].

Reliability of exploitation of heat networks is in many aspects determined by the trouble-free operation of segments situated in heat chambers. According to the Mosenergo data [8], the damage of pipelines in heat chambers is stronger than in their linear part by a factor of 10. An increased air humidity, which is explained by leakage of surface waters through the broken overlaps and leaky caps of manholes and leakages of a heat carrier through gland seals of valves, is characteristic of heat chambers.

Due to the temperature difference between chamber walls and equipment, convective heat flows are formed, which leads to condensation of water vapors and appearance of drops. Corrosion of metal constructions is observed along with corrosion of equipment and pipelines. Destruction of stairs limits the access to objects and causes the appearance of "abandoned" chambers [8].

An opinion was formed rather long ago in the engineering community that the existing practice of anticorrosion protection of the pipes during assemblage not only contradicts the regulatory documents in many aspects [3, 4] but also has eliminated itself economically. The fraction of expenses for pipes in repairs of distribution heat networks does not exceed 10%, while 25–30% is assigned to the "improvement" item [9]. With the service life of pipelines of 10–12 years (sometimes much shorter [5]), the efficiency of investment in heat networks is very low and the application of higher-cost anticorrosion solutions is reasonable [10–13]. These solutions are quite warrantable due to an increase in service life and trouble-free operation of networks.

The most effective methods of decreasing the corrosion destruction of pipelines at a heat-carrier temperature up to 150°C is the sacrificial protection of the pipes isolated by materials with pH of the water extract from 4.5 to 9.5 with a plated aluminum coating [9]. Thus, the tread protection with aluminum does not have limitations neither by the insulation type nor by the operational temperature schedule of the heat network. According to evaluations [11], the rise in price of the pipe in the industrial production does not exceed 25%.

Protection of a steel pipeline is provided by sacrificial action of a barrier aluminum layer and insoluble products of its oxidation having a large specific volume and blocking the open pores. In practice, this means that even with thin (50–100 μm) coatings, which are characteristic of foreign technologies, initially forming point regions of corrosion destruction are passivated and the state of the coating remains invariable for many years [14].

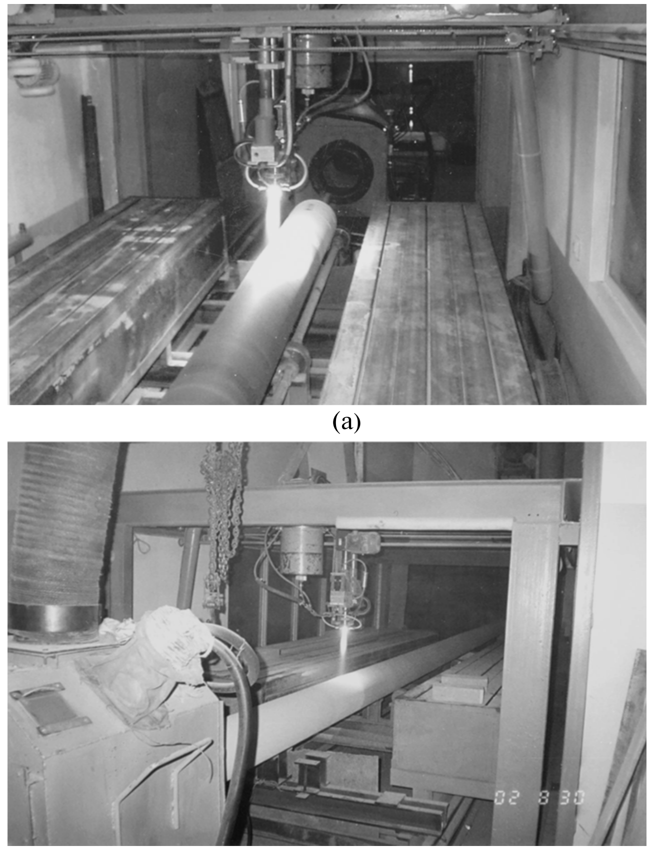
According to [4], a plated aluminum protective coating is deposited on pipes in plant conditions using a gas-thermal method with the help of gas-flame or electric-arc metallization apparatuses in two layers the summary thickness of which should be 250–300 μm.

For a mid-aggressive character of the environmental effect, a coating of such a thickness without painting provides a service life of metal constructions of 50 years. In contact (immersion) with water heated to 100°C, this coating protects steel for 30 years.

Not disputing the advantages of metallization apparatuses and gas-plasma burners we should note that plasmatron-deposited coatings possess higher qualitative characteristics [11] satisfying all requirements of regulatory documents in this case. A comparative analysis performed in [11] also shows manufacturing advantages of plasma deposition with the use of an air–propane mixture as a plasma-forming gas.

In this work we deposited an aluminum coating 250 μm thick on the pipes of heat networks by means of plasma deposition of aluminum of PA3 and PA4 grades using a supersonic plasmatron with a power of 80 kW using an air–propane mixture (Fig. 1) according to GOST (State Standard) 60-58-73. Operational costs with the use of such a deposition technique did not exceed the costs for electrometallization or high-quality painting with the Alpol protector for example.

In conditions of pilot production, the pipe was prepared for deposition in a passage multinozzle shot-blasting installation with lump cast-iron shot according to GOST 11964-81 to degree 1 according to GOST 9.402-2004 and roughness of 15 μm according to GOST 2789-73.



(a)

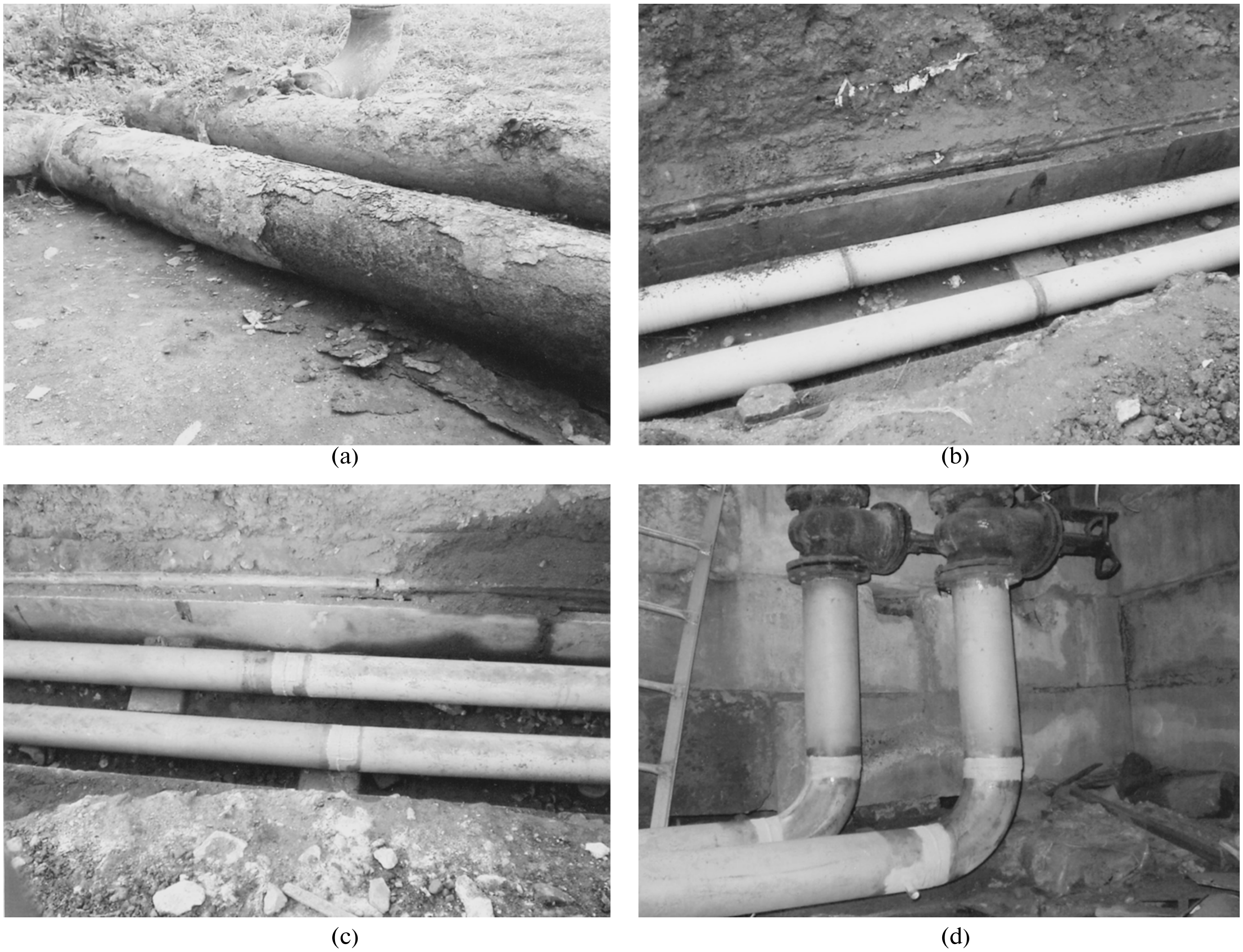
(b)

Fig. 1. Flow production line of network pipes with aluminum plasma coating. (a) View from the plasmatron side and (b) view from the shot-blasting chamber.

The sequential arrangement of the shot-blasting installation and plasmatron made it possible to shorten the time between preparing the surface and deposition to 1 min, which is substantially shorter than it is required according to GOST 9.304-87 Gas-Thermal Coatings. A short interoperational interval promotes a high coating quality even at the humidity of compressed air and high oxidation rate of the post-cleaned pipe characteristic of the summer period.

The plasmatron power and velocity of the plasma jet yielded high process productivity (tens of kilograms per hour), acceptable porosity (2–5% by the results of hydrostatic weighing [15]), and necessary adhesion of the protective aluminum layer with steel (no lower than 25 MPa), which was determined using a shift procedure [15]. High mechanical properties of the coating confirmed later that damages in rigid assemblage conditions along the route (pipe rotation with installation tools, fastening with a steel rope) were absent.

The plasmatron design and automated remote control system were adapted to conditions of flow pipe production. An insulated working place of the operator



(a) (b) (c) (d)

Fig. 2. Example of the repair of the segment of the heating main. (a) Pipes extracted from a channel of the drowned segment, (b) the mounted segment of the heating main with protected pipes, (c) the same segment after protection of joints with gas-plasma deposition, and (d) repair of pipes in a heat chamber.

made it possible to perform visual monitoring of aluminum deposition on the pipe surface and passage to manual control if necessary. Power manual operations were only the assembly and removal of pipes from a roller conveyor.

Repair of the emergency segment of distribution heat mains, including a heat chamber, was performed using a seamless pipe 219 × 8 mm with an aluminum sacrificial coating with the use of hydrophilic insulation made of silicate cotton (Fig. 2).

During control pitting of the heat mains and visual inspection of pipelines of a heat chamber in the course of preparing for the next year's heating season, no visible corrosion signs of steel and protective coating were found. Indirect evidence of rigid operational conditions of the coating in drowned channels were numerous bitumen spots on the upper part of the supplying pipe due to overheating of the coating insulation layer made of ruberoid (Fig. 3).

Protection of weld joints in assembly conditions is an independent and urgent problem. Protection of segments of weld joints of pipelines with a plated aluminum coating and elements of heat-network pipelines should be performed in field conditions using manual gas-plasma or electric-arc metallizators [4]. However, the usual practice of protection of seals is their painting [9].

Works on protection of weld joints and zones of their influence on the presented emergency section were performed by gas-plasma deposition of aluminum using oxygen–propane fire since the obtained coating was close to the main protective layer deposited using oxygen–propane plasma by the chemical composition and structure. In contrast to usual scratching practice [9] (cleaning of the object surface using metallic brushes

Fig. 3. View of the pipe in a control pit.

before coating deposition) was performed using the shot-blasting installation with a circulation motion path of the shot.

Tight working conditions in inaccessible channels hamper the use of standard equipment for gas-plasma deposition. In connection with this fact, specialists at ZAO Tekhnologii Svarochnogo Proizvodzstva (Yekaterinburg) developed a profiled burner, which ensured easy access to the lower joint part. With its help, seams of the emergency segment were protected (Fig. 4).

Impregnation of a hot coating with butyral resin was used for additional protection of seams and the zone of their thermal influence as the most vulnerable segment of a pipe. To provide anchoring and attaining the "coating–pipe surface" interface by impregnation through open pores, impregnation was performed immediately after deposition of aluminum.

Thus, plasma deposition of aluminum on pipes in plant conditions and gas-plasma treatment of weld joints during assemblage can be considered as a system of complex protection of emergency segments of distribution heat networks against the external corrosion during their construction and repairs.

The estimated cost of works during deposition of the plasma aluminum coating in pilot production conditions allowing for regional indexes of recalculating the estimated cost of building for application starting from January 1, 2013, for pipes with a diameter above 100 mm is approximately 2217 rubles/m^2, which corresponds to evaluations presented in [13] and agrees satisfactorily with federal unitary prices.

When organizing large-scale industrial production, in order to accelerate the process and reduce its price, a high-cost shot-blasting cleaning should be undoubtedly replaced by pipe cleaning in a passage shot-blasting chamber with the preliminary pipe heating to 300°C in an induction furnace.

Fig. 4. Protection of weld joints and the thermal influence zone by gas-plasma deposition of aluminum in assembly conditions (a protected seam to the right).

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